PRELIMINARY NSA SONDE ANALYSIS
PTU vs. GPS GEOPOTENTIAL HEIGHTS

Michael Ritsche, ARM BBSS Associate Mentor

Introduction:
Recent upgrades to the BBSS system software at NSA have made it possible for us to retrieve GPS calculated geopotential heights (referred to as GPS heights hereafter) along with the normal PTU calculated heights (referred to as PTU heights hereafter). This report covers a preliminary investigation of the differences (PTU heights – GPS heights) in these heights and attempts to characterize them.

The data included in this preliminary study came from all available ARM/NSA GPS radiosonde launches from 06/23 – 07/31/2006. Because we had some hardware and software problems, only 31 of the 80 soundings were suitable for the analysis. An error in an output script that was installed on 7/12/2006 resulted in failure to write the GPS height data to the files used for analysis. We corrected this error and future soundings will output all of the required data.

Analysis:

Figure 1 shows the by-sounding statistics of the differences. The average difference between the PTU and GPS heights during any one sounding is less than 15 m. The sounding-average differences range between 31.6 m [20060711:1700] and 0.04 m [20060709:0500]. The standard deviations of the differences within a sounding are of the same order of magnitude as the averages, indicating that the sounding-average differences are not statistically significant.

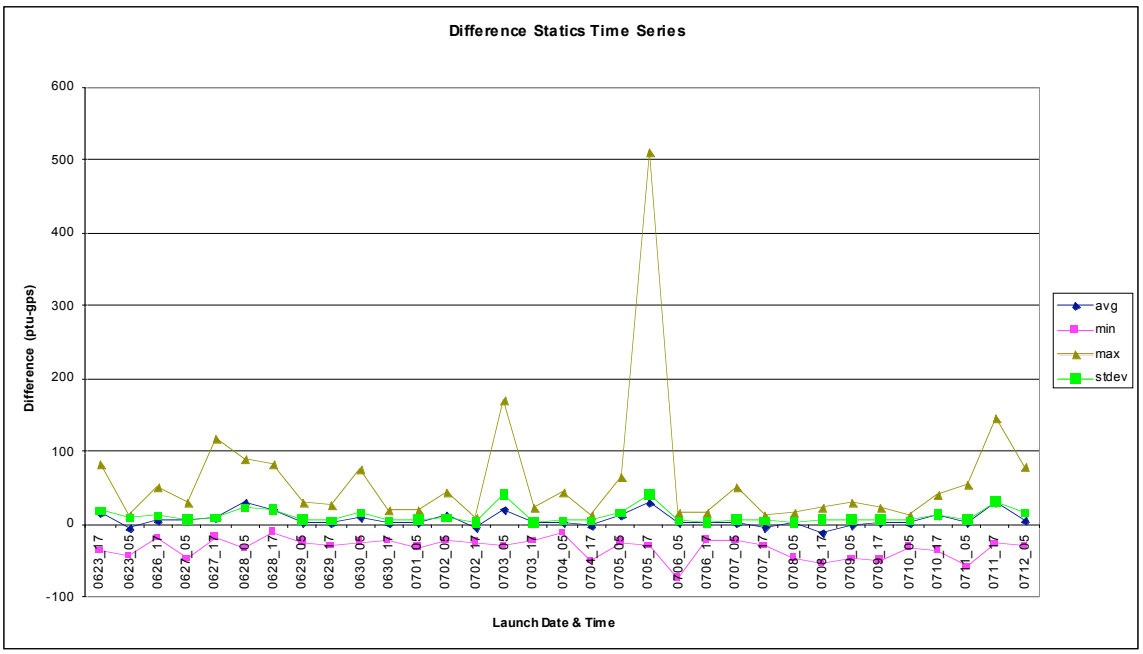

Figure 1: Time series of by-sounding height differences (PTU-GPS) in m.

Within the soundings, the by-sample differences range between 510 m and -58 m. The by-sounding minimum sample differences appear to be more stable than the by-sounding maximum sample differences. The minimum differences show little variation and in general are in the teens and twenties. On the other hand, the maximum differences show quite a bit of variation, with values in general between the tens and hundreds of meters difference. The largest maximum difference is 510 meters. Overall, the PTU heights are greater than the GPS heights.

Figure 2 shows the overall average height differences for the following significant levels: 1000mb, 900mb, 850mb, 700mb, 500mb, 250mb and 100mb. This was done in order to determine if the largest differences were occurring in a specific portion of the atmosphere.

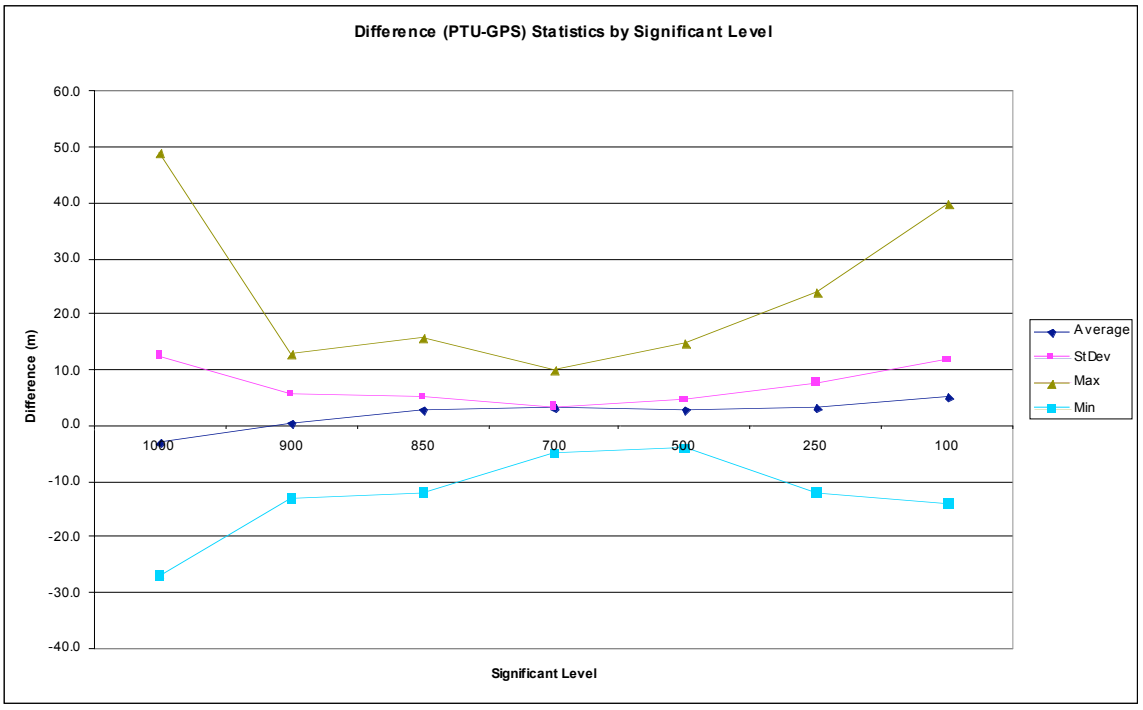

Figure 2: Difference Statistics by Significant Level.

The average difference is positive in all cases except at the 1000mb level. This suggests that for these 31 launches, in general, the PTU height is greater than the GPS height except near the surface. There are a few notable exceptions (06/27 1700 GMT, 07/04 0500 GMT, 07/05 1700 GMT, 07/11 0500 GMT) where the GPS height was a negative value leading to the large maximum difference at 1000mb. Overall, the best agreement between to two heights occurred in the mid-troposphere. Soon after launch, average differences decreased as the balloon neared 900mb and continued decreasing through 700mb. From 700mb to 500mb there was little change in the average differences, but from 500mb to 250mb they increased and continued increasing through 100mb.
The maximum differences decreased rapidly from 1000mb to 900mb and were of similar magnitude from 900mb through 500mb. From 500mb through 100mb the maximum differences slowly increased from the smallest value of 10 meters through 40 meters.

The minimum differences decreased from 1000mb through 500mb. From 500mb through 100mb the minimum differences increased, but were approximately a factor of 4 less in magnitude than the maximum differences. This suggests there may be a slight positive difference bias that increases with altitude.

We also plotted the height differences of every launch against pressure (Figures 3 and 4). This was done in order to determine if there were any systematic differences as suggested by Figure 2.

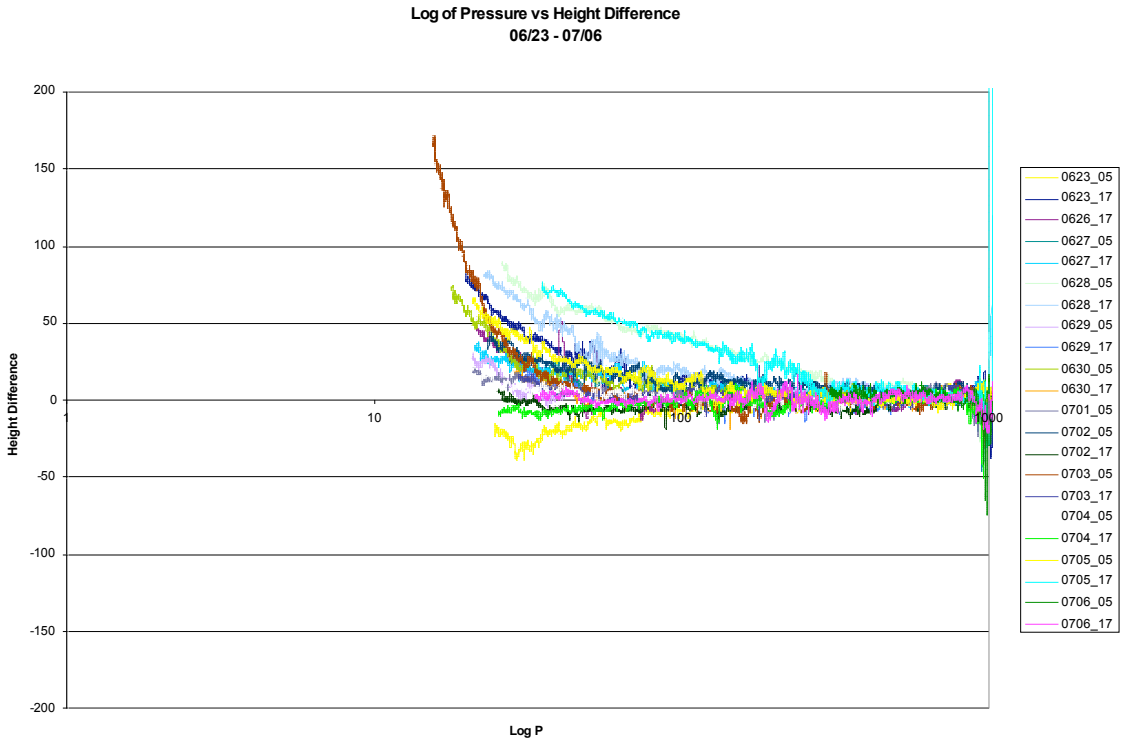

Figure 3: Height Differences vs. Pressure 06/23 – 07/06.

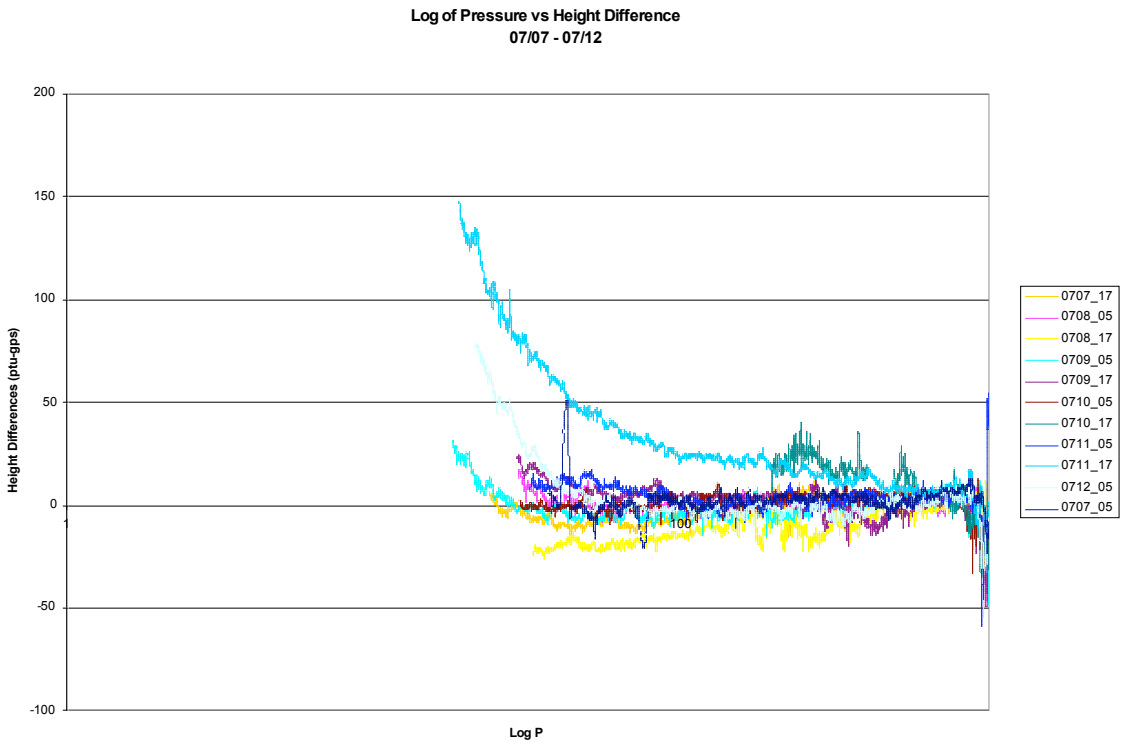

Figure 4: Height Differences vs. Pressure 07/07 – 07/12

In general, these two graphs show that there appears to be systematic negative difference near the surface. In their own study (Jauhiainen et al., 2005), Vaisala, the radiosonde manufacturer found that this negative bias could be accounted for by assuming a small (-0.1 hPa) constant pressure offset. Figure 5 is taken from their report on the subject. The source of this pressure offset, however, is not clear. Presumably, the GPS height determination is independent of the pressure. We will examine this issue further as the analysis continues.

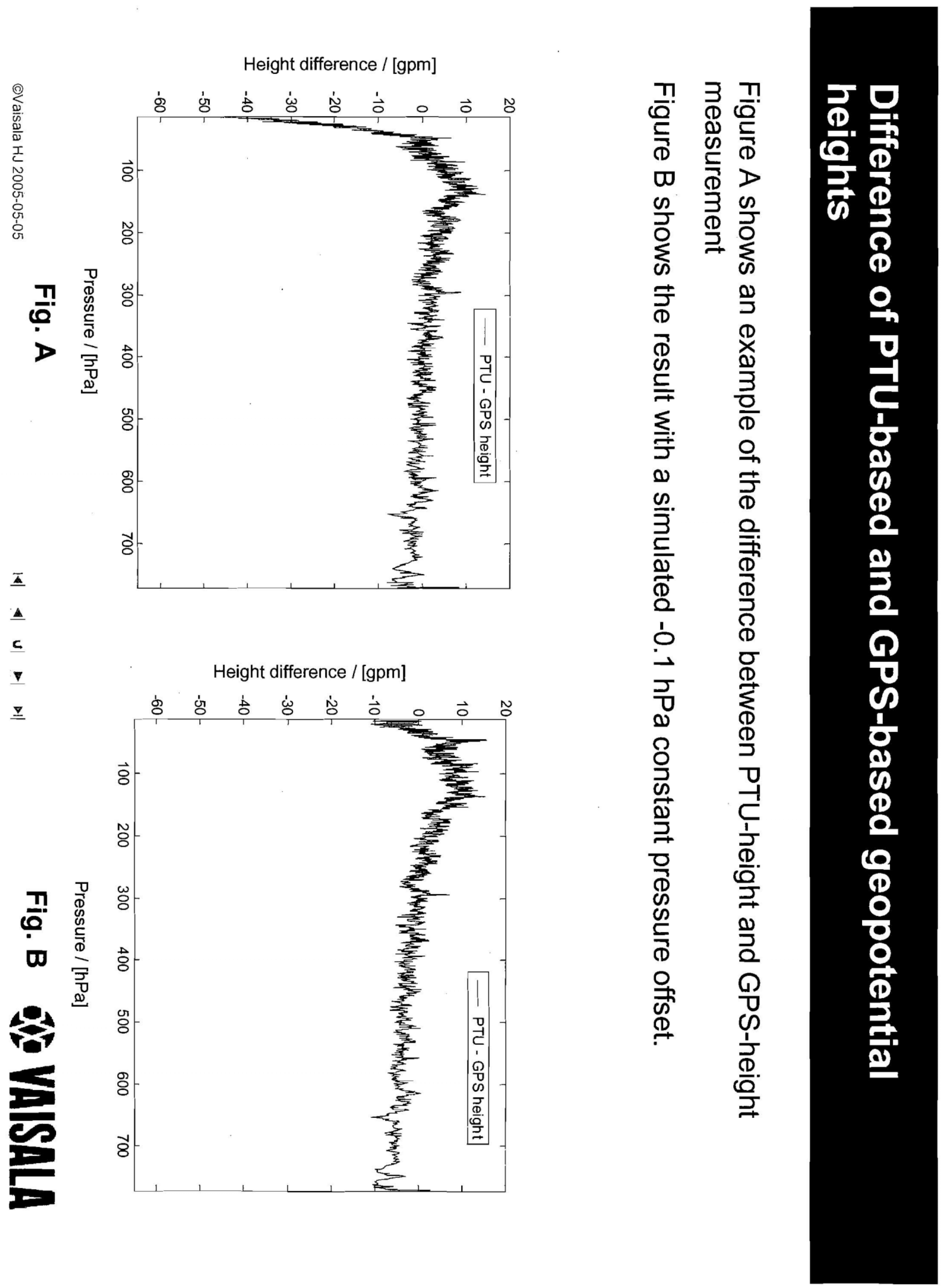

Figure 5: Vaisala Pressure Offset (From Jauhiainen et al., 2005).

Figures 3 and 4 also show the overall trend for a systematic positive difference that grows larger with increasing altitude. Further investigation into the data show that 13 of the 31 launches have a large degree of increasing positive differences (increasing to above 30 meters) while only 5 of the 31 launches show differences of less than 10 meters (including negative values). The remaining 13 show a slight positive bias (up to 20

meters) but are within the manufacturers specifications for GPS vertical position accuracy (20 meters). In 4 of the 13 that show an increasing positive difference, the difference begins early in the launch and is near 90 meters by the end, one case exceeding 150 meters.

The final analysis involved plotting the actual 100mb GPS and PTU heights for each available launch (Figure 6). It was thought that since the 100mb pressure surface is located in the stratosphere for NSA launches the change in the height of this surface over time would be less than and more smooth compared to pressure surfaces in the Troposphere. Our intent was to try to characterize one height calculation method as having more variability over time than the other, perhaps suggesting it was less accurate at that height comparatively.

Figure 6: Time Series of 100mb Height

Figure 5 shows that, in general, there is good agreement between the two methods. The data appear to trend together. The launches in which they do not trend together are for the most part associated with the largest differences shown in Graphs 3 and 4. These are the 06/23 1700 GMT, 06/28 0500 GMT, 06/28 1700 GMT, 07/05 1700 GMT and 07/11 1700 GMT launches. Overall there are too few data points to get a good idea which method appears to be less variable. Additionally, the differences between the two methods were less than 50m for all data points. At this time, there is no consensus on the magnitude of differences that are significant.

Recommendations:
Further investigation of the causes of the systematic differences is required. There are too few data points to pinpoint a cause or suggested cause. Additional data also should be investigated at various times of the year to determine if there are surface conditions or solar influences. In the near future upgrades to the SGP Central Facility BBSS System will allow for the GPS data to be collected with their sonde launches. Comparisons to their data to determine if similar problems occur should take place.

Reference:

Jauhiainen, H., Lehmuskero, M., and J. Akerberg, 2005. Vaisala RS92 radiosondes offer a high level of GPS performance with a reliable telemetry link. WMO Technical Conference on Meteorological and Environmental Instruments and Methods of Observation (TECO-2005). Bucharest, Romania, 4-7 May 2005.